SPECIAL ARTICLES, NOTES, AND EXTRACTS.

THE CLIMATE OF THE HISTORIC PAST.

By ELLSWORTH HUNTINGTON. Dated Yale University, New Haven, Conn., November 10, 1908.

INTRODUCTION.

Among the factors that have influenced human development an important place must be accorded to climatic changes of all types, from the great fluctuations of the geological past down to the small fluctuations in temperature, rainfall, and other elements, which now take place from year to year.

The complex series of climatic changes grouped collectively under the title of the Glacial Period caused world-wide and profound "repressive evolution." Under the stress of repeated transitions from cold, damp glacial epochs to warm, dry interglacial epochs, thousands of species of plants and animals were extinguished, while those which survived were forced to develop with phenomenal rapidity in order to adapt themselves to new conditions. The excessive changes of environment, both animate and inanimate, to which early man was then subjected are considered by evolutionists to have exerted a most marked influence upon the growth of his intelligence.

Even the small fluctuations of climate which now occur from year to year and decade to decade produce noteworthy results. An exceptionally rainy season may flood the Ohio River and cause the loss of millions of dollars' worth of property. Such floods inevitably give rise to want and misery, and perchance to crime, among the hundreds of families whose means of livelihood are destroyed. In India and China a scarcity or even a postponement of the monsoon rains often subjects millions of people to the horrors of famine. Similar scarcity of water in Arabia has more than once so impoverished the Arabs that they have risen in desperate revolt against the Turks, their nominal masters.

Between the climatic changes of the glacial period and the temporary changes which now occur within the observation of a single generation there is a large gap. It has often been assumed that the two types of change are unconnected, the one being due to some vast cosmic cause whose nature is still in dispute, the other to local irregularities in the circulation of the earth's atmosphere. A study of the climatic history of Asia seems to require a modification of this view, and to give ground for the hypothesis that during historic times there have been changes of climate whose characteristics were intermediate between those of the glacial period and those which now occur within the limits of contemporary observation. The effects of such historic changes must, it would seem, have been intermediate between the epoch-making results of the Glacial Period and the slighter, but by no means unimportant results of the floods, droughts, unseasonable frosts and similar phenomena of to-day.

Meteorologists have not as a rule accepted the hypothesis of important historic changes of climate. They have held that while small changes may have occurred, the general course of climate has been uniform and that a slight fluctuation in one direction during a period of a few years has always been compensated by a slight fluctuation in the other direction at a succeeding time. In proof of this they point to the unquestioned fact that the meteorological records of the past two hundred years or less either indicate no permanent change whatever or one so small that it is less than the uncertainty of the numerical averages that describe the climate. Being accustomed to appeal to the absolute evidence of figures, technical meteorologists have given too little weight to other less exact, but no less conclusive lines of evidence, which alone are available in determining the nature of the climate of past times. The present article is written for the purpose of setting forth some of these lines of evidence. It is impossible here to give more than the briefest outline; but a full presentation is the less necessary as practically all the evidence here presented in abstract has been set forth with full details in the author's "The Pulse of Asia,"[1] and in various magazine articles. If the following pages appear to contain a large amount of conclusion and a small amount of fact, it must be borne in mind that for every fact here set forth in evidence of climatic change during historic times a dozen have been set forth elsewhere.

Climatic cycles.—At the dawn of human history the climates of the main portion of Asia, and apparently of all continental regions between the twentieth and fiftieth parallels of latitude, appear to have been decidedly moister and, presumably, cooler than is now the case. The change from the climates of that time to the warmer and drier conditions of the present apparently took place irregularly in a pulsatory fashion. A comparison of the state of affairs two thousand years ago, or more, with that of to-day, suggests that the slow swing from the cold, moist climate of the last glacial epoch to the warm, dry climate of the present post-glacial epoch is as yet scarcely completed. A fuller study of the data for intermediate periods suggests that the swing is taking place in waves or pulsations. Apparently climatic cycles of all sizes are now in progress. The shortest are those of three, eleven, and thirty-five, or thirty-six years, whose existence is maintained by Lockyer, Blandford, Bigelow, Brückner, and others. Next come cycles measured in hundreds of years. In studying the 35-year cycles of Brückner,[2] Clough[3] concludes that certain data suggest a cycle of three hundred years. Evidence from Asia, which is set forth in outline below, indicates that cycles lasting considerably more than three hundred years, possibly a thousand or more, have occurred during historic times. The series of cycles is completed so far as recent geological time is concerned, by glacial epochs and glacial periods that appear to have lasted thousands and tens of thousands of years. The amount of the change of climate during a given cycle appears to vary roughly as the length of the period. Changes of every degree may be in progress at once, the small being superposed upon the larger, and these in turn upon those of still greater dimensions. All seem to produce results of the same kind, altho of extremely diverse magnitude; which suggests, tho it by no means proves, that all the changes may be due to the same cause.

PART I. THE OLD WORLD.

Nature and location of evidence in Asia.—The chief evidence which has given rise to the preceding hypothesis comes from western and central Asia. Here the writer has investigated the subject in various parts of an area as large as the United States. The area extends from longitude 35° E. in Asiatic Turkey to 91° E. in Chinese Turkestan east of the famous lake Lop Nor, and from latitude 30° N. in eastern Persia and northwestern India to 45° N. on the border between Siberia and China. The evidence may be grouped under three heads: (1) Physical phenomena such as changes in the lengths of rivers which disappear in deserts; the appearance or disappearance of springs; changes in the salinity of springs and rivers; fluctuations in the levels of lakes which have no outlets; the deposition of alluvium or the formation of terraces by the dissection of such alluvium. (2) Phenomena relating to the distribution of plants and animals. (3) Human phenomena including (*a*) ruins and other proofs of man's permanent presence in regions now climatically unfit for occupation; and (*b*) legends, traditions, and historic records. As a rule all three kinds of evidence are found associated together. A brief description of eight distinct basins in various parts of the region defined above will show the basis upon which the conclusions

[1] Ellsworth Huntington: The Pulse of Asia. Boston and New York. 1907. 8vo. 415 p.

[2] E. Brückner: Klimaschwankungen seit 1700. Vienna. 1890.

[3] H. W. Clough. Synchronous Variations in Solar and Terrestrial Phenomena. Astrophysical Journal, 1905, 22:42–75.

of this article are based. The basins are selected not because of the strength of the evidence which they present, but because they happen to be the eight localities in which the writer studied the subject most carefully. Five of them, namely, the basins of Pangong in Tibet, of Lop and Turfan in Chinese Turkestan, of Seyistan in Persia, and of the Caspian Sea, are occupied by salt lakes whose rise and fall afford an accurate index of variations of climate. One of the others, that of Gyul-jük in Turkey, contains a slightly brackish lake which sometimes overflows and sometimes is without an outlet. The periods when it is without an outlet appear to be times of exceptional aridity. The other two basins, those of Kashmir in India, and Son Kul in Russian Turkestan, contain normal lakes which overflow at all times. Their evidence is of a different type from that of the others.

(1) *The Vale of Kashmir.*—The famous Vale of Kashmir is blest with a climate very different from that of India in general. Lying in latitude 34° N., at an elevation of over 5,000 feet above the sea, the Vale, which is really a basin floored with an alluvial plain, has long, cold winters, with an abundant fall of snow which often remains on the ground well into March. The summers are warm; but in the autumn snow sometimes comes so early as to ruin part of the rice crop. Moraines and other signs of glaciation in the mountains, and river terraces in the valleys, indicate that the climatic history of Kashmir has been as complex as that of other parts of Asia or Europe or America. A circumstantial tradition relates that when man first inhabited the Vale the climate was so cold as to make agriculture impossible. The inhabitants, so it is said, were pastoral nomads. They spent the summers in Kashmir, but in winter evil demons caused so much snow and such low temperature that it was impossible to remain. The nomads were obliged to cross the southern range of the Himalaya as to the warm, low plain of India. An appeal to the gods caused the country to become warmer and less snowy, whereupon the nomads changed their habits and settled permanently in Kashmir to practise agriculture.

The tradition is recorded in the work of the Kashmiri historian Kalhana[4], 1148–49 A. D., and is also mentioned by the Chinese pilgrim, Huien Tsiang[5], who visited the country in the seventh century of our era. Its details, apart from the calling in of the gods, are so reasonable and so unlike what the story-teller would invent, and they agree so perfectly with the phenomena in other parts of Asia, that they possess a high degree of probability. At the time of Huien Tsiang Kashmir appears to have been as populous as now, and to have contained a highly prosperous agricultural population which lived much as the Kashmiris do to-day. Historic accounts of the blocking of the gorge of the Jhelum River by detritus from the mountains, causing a rise in the level of Lake Wular soon after the time of Huien Tsiang, confirm the legend. They seem to indicate that the amount of vegetation upon the mountains had decreased so far under the influence of diminished rainfall that the soil and loose rock upon the slopes were no longer held in place and were washed into the rivers. Various records of early snow and of the freezing of the river in the middle ages suggest, but do not prove, that the climate may once more have become slightly cooler or moister than it was in the days of Huien Tsiang or is now. The evidence of Kashmir alone would be of slight weight, but its agreement with that from remote regions where climatic conditions are very different gives it a high degree of value.[6]

(2) *Lake Pangong.*—Two hundred miles east of Kashmir on the farther side of the Himalaya Mountains the salt lake of Pangong[7] lies, at an altitude of 14,000 feet, on the western border of Tibet. The lake owes its origin to glaciers which scoured out a long valley, forming a series of basins with a length of over a 100 miles and an average width of only 2 miles. Since the retreat of the last great glacier the level of the lake has fallen markedly. At first it overflowed to the Indus River, but later the water fell below the level of the outlet. Just when this happened we can not tell, but it was certainly long after the retreat of the ice. Since that time the diminution of the lake has proceeded until now its surface is at least 60 feet below the level of the former outlet. Sometimes, as is shown in the article referred to above, the water has risen for a time, as appears from lake deposits lying over those of streams. Again it has fallen or been almost stationary for considerable periods. Thus six well-marked strands have been formed at successive levels from 60 feet down. The upper strands are marked by large beaches and high cliffs which could only have been produced by long periods of wave action. The lower and younger strands are less strongly marked. They are so well preserved, however, that it seems improbable that they can be more than a few hundred years old.

The length of time since the climax of the last great glacial epoch has been very variously estimated. From a comprehensive study of all the available data in America, Chamberlin and Salisbury[8] state that the estimates of the time elapsed since the beginning of the last ice-retreat range from twenty thousand to fifty-six thousand years. The formation of the uppermost of the six strands of Pangong can not have begun until a much later date; for before its inception the ice must have retreated from the lake, and the climate become so far ameliorated that the water ceased to overflow. The formation of the strands can scarcely have occupied more than half of post-glacial time, or from ten thousand to thirty thousand years. Authentic human history goes back fully six thousand years in Egypt and Babylonia. If the ice age in Asia was coincident with the ice age in America, it is hard to avoid the conclusion that at least one and perhaps several of the six strands of Pangong must have been formed during the period covered by human history. If this is so, it means that during that period there have been one or more changes of climate. The changes appear to have been sufficient to exert an influence upon the habitability of regions which are on the verge of great aridity on the one hand, or of unduly low temperature on the other.

(3) *The Lop Basin of Chinese Turkestan.*—North of Kashmir and Pangong, on the other side of the great central plateau of Tibet the Lop or Tarim basin lies with its floor from 2,500 to 5,000 feet above the sea. The basin occupies the very heart of Asia. It forms the major part of Chinese Turkestan. Its length is 1,400 miles and its maximum width from north to south 400 miles, embracing an area as large as the portion of the United States east of Lake Michigan and north of Tennessee. Except on the northeast it is surrounded by lofty snow-capped mountains, those of Nan Shan on the east, Kwen Lun on the south, the Pamirs on the west, and Tian Shan on the north. On every side mountain torrents flow swiftly down to the great plain which forms the floor of the basin. A few which combine to form the Tarim River reach the salt lake of Lop Nor in greatly diminished volume. The rest wither to nothing in sand and gravel. Most of the basin is desert. At the foot of the mountains lies a broad strip of gravel from 5 to 40 miles wide, like an enormous naked beach. This has been produced by the deposits of countless mountain streams, many of which are themselves lost in its thirsty depths.

[4] See M. A. Stein: The Ancient Geography of Kashmir. Journal of of the Asiatic Society of Bengal, 1899, 68: 65.

[5] See Samuel Beal: Si-Yu-Ki. An account of the journeys of Huien Tsiang. London. 1884. 2 vols. vol. 1, p. 149.

[6] For an account of the evidence of changes of elements in Kashmir see "The Pulse of Asia," pp. 36–46. For a fuller discussion see Bul. Am. Geog. Soc, 1906, 38:657–686.

[7] Pangong: A glacial lake. Jour. of Geol., 1906, 14:599–617, esp. 614 ff.

[8] Geology, Vol. III, p. 420. In The Falls of Niagara, 1907, p. 30 et seq., J. W. W. Spencer gives various estimates of the age of the Niagara gorge, on which are based the most reliable estimates of the length of the period elapsed since the last glacial epoch.

Within this strip of gravel lies a zone of vegetation from 1 to 20 miles wide. This is the only part of the basin where vegetation is abundant. Most of the oases of the country are located here. Within the ring of vegetation lies the desert of Taklamakan, one of the great sand deserts of the world, 200 or 300 miles wide and 900 miles long from east to west. At its eastern end sand gives place to lifeless clay and salt in the midst of which the shallow, marshy, saline lake of Lop Nor occupies an almost imperceptible depression.

The Lop basin contains abundant evidences of climatic changes, and has been discussed in detail by the writer in "The Pulse of Asia." Thruout the basin the amount of vegetation has greatly decreased in recent times without the intervention of man. On the lower slopes of the Kuenlun mountains the dissected condition of numerous deposits of loess shows that a cover of grass prevailed at no remote date, but has now disappeared. In the zone of vegetation plants of all kinds show signs of a process of drying up which has been in progress for centuries. Tamarisk bushes stand upon mounds from 5 to 60 feet high, a sure sign of the lowering of the level of ground-water; poplar forests which once extended for scores of miles now form wastes of branchless dead trunks like gaunt gray skeletons; and beds of dead reeds cover hundreds of square miles. It has often been asserted that the destruction of forests has been the cause of the dimunition of rainfall. In the Lop basin the opposite appears to be the case; the supply of water has diminished and therefore the forests have died. Rainfall unquestionably controls forestation, but neither in the Lop basin nor in other parts of central and western Asia is there any good evidence that forests have an appreciable effect upon rainfall.

Another important line of evidence is found in the relation of rivers to the desert of Taklamakan and to ruins of ancient dwellings. On the south side of the Lop basin, from Khotan eastward to Lop Nor, the writer examined seventeen streams which are worthy of notice, because of their size or because they support oases. All but four come to an end in the zone of vegetation, where they spread out and disappear either naturally or because used for irrigation. Hence it is impossible to determine whether or not they have decreased in length. At the lower ends of the other four, old channels are found lined with dead forests which prove that the streams once extended from 8 to 25 miles farther than is now the case before finally becoming swallowed up in the sand. One of the four rivers, the Keriya, may have been shortened by the withdrawal of its water by man for irrigation, but the other three, the Niya, Yartungaz, and Endereh, had diminished in size before the few present inhabitants came to the region, and at a time when their waters were entirely unused.

On the lower portions of thirteen rivers, out of the seventeen, one finds the ruins of Buddhist towns dating back a thousand years or more. In almost every case the ancient towns were much larger than their successors, and, with three possible exceptions, the older ruins are situated so far out in the desert, or upon rivers so small and saline, that it would be impossible again to locate towns of equal size in the same places, unless a far better system of irrigation were introduced. The old system, of which portions remain in three places, was precisely the same as that of to-day; that is, it was the simplest of all systems of open canals dug in any kind of soil, with nothing to prevent leakage. The ruins are in some cases buried in sand, but this can not have been the cause of their abandonment; for others lie in regions quite devoid of sand. In some cases it appears that the old towns were abandoned for lack of water; in others, for instance at Endereh, there is still a fair supply of water but it is now so saline that it can not possibly be used for irrigation, altho there is abundant evidence of former cultivation on a large scale. Numerous springs have grown saline in similar fashion.

In addition to the dead vegetation, the shortened rivers, the increased salinity of the streams and springs, and the waterless ruins, there are other facts in the Lop basin which point to desiccation. Ancient Chinese accounts and traditions tell of much-frequented roads which are now unused and unusable. One such went northward from Keriya thru 200 miles of sand, where no native dare go in modern times for lack of water, and no foreigner has gone except the intrepid Sven Hedin. In the desert east of Lop Nor, Hedin discovered the milestones and waymarks of another caravan route located in a region which is now so dry that his camels went eleven days without water.

The lake of Lop Nor lies about 100 miles to the southeast of the place where Hedin found his second old road. Around the lake a number of elevated strands, most of which are more ancient than those of Pangong, indicate that during successive epochs the lake expanded enormously. According to universally accepted geological methods of interpretation, these expansions must have taken place during the Glacial Period. Old Chinese maps and records indicate that within historic times the lake was at one period much larger than now, and the evidence of ruins and vegetation confirms the conclusion. On every side of the lake a vast salt plain indicates the extent of the water not many centuries ago. The south shore of the plain is skirted by a road which is used by two or three caravans every year, in spite of the absolutely uninhabited desert which it traverses for 300 miles. At a salt spring called Chindelik the road leaves the edge of the plain, which here forms a deep embayment to the south, and runs straight across the bed of the old lake. Thinking that if the lake had ever covered the salt plain during historic times there must be an old road skirting the former shore line, the writer searched for such a road and to his surprise found two. One follows the lowest of the old strands, 12 feet above the present water level, and the other runs along the top of the high bluffs of gravel which mark the second, or 30-foot strand. The upper road traverses a plain of sand and gravel, and is marked at intervals by cairns of stones, one large and the others small. For two days the writer zigzagged between the two old roads, and at various points saw that they always bear the same relation to one auother and to the strands. The present road runs direct from Chindelik, where there are fairly good springs, to Sachgan Sai, the next source of water, where the springs are very saline. The distance is about 24 miles, a long day's journey for loaded oxen, donkeys, and camels, even tho the track is level and easy. By way of the old road, along the 12-foot strand, the distance between the same points is about 32 miles, too much for one day's journey, tho the track is perfectly level and almost ideal in texture. By way of the higher road, above the 30-foot strand, the distance is a mile or more greater than by the other old road, and the track runs thru heavy sand in some places and up and down across valleys in others. Along both of the ancient roads, as well as along the modern road, the country is absolute desert, with neither water, wood, nor forage from Chindelik to Sachgan Sai. There is absolutely no reason for the existence of either of the old roads unless the present route was impracticable because covered with water, and there is equally little reason for the road above the 30-foot strand unless the road on the 12-foot strand was impracticable for the same reason.

Previous to the writer's visit the natives of Lop Nor had apparently never heard of the road above the 30-foot strand. They knew all about the other, however. Two or three hundred years ago, according to their account, the lake of Lop was larger than it is now, and fish were more abundant. Their ancestors used to bring fish in canoes to a place near the spring of Lachin where to-day there is nothing but a plain of dry salt. Thence they carried the fish on donkeys to Sachow, the most western town of China proper. The salt plain

between Chindelik and Sachgan Sai was at that time so wet as to be impassable, and the road along the 12-foot strand was used. It seems safe to infer that the older road along the 30-foot strand was used at a time when Lop Nor stood so high that the easier route along the younger strand was still covered with water. A careful study of the phenomena of all parts of the great Lop basin leads to the conclusion that desiccation has been the general rule, but that it has not progressed uniformly. About 300 A. D. it appears to have progressed with extraordinary rapidity, for a large number of ruins in the Taklamakan desert were abandoned at that time. From the descriptions of the country by Chinese travelers it seems probable that in the sixth century of our era, or thereabout, the climate was as dry or drier than it now is.[9] Half a millenium later, during the middle ages, towns were again located in places such as Lachinata near Chira, or Yingpen in the far northeast, where the water supply is now wholly inadequate. Apparently, at this time, there was an epoch of some centuries during which the climate again became somewhat moister than is now the case. It is not possible to speak with certainty, but it seems as if the road along the 12-foot strand might belong to the mediaeval epoch of more abundant water supply, and the older road along the 30-foot strand to the earlier period of more propitious climate some two thousand years ago.[10]

(4) *The basin of Turfan.*—Many of the peculiar features of the Lop basin are repeated in the small basin of Turfan which lies below sea-level about 200 miles north of the eastern part of the Lop basin. To-day every available drop of water from above ground is used for irrigation, and about 30,000 people are thereby supported. In addition to this, a vast number of "kariz" or underground channels have been dug to take advantage of the water which flows far beneath the surface. By this means about 20,000 additional persons are supported. Nevertheless only a small part of the basin floor is cultivated. In ancient times the system of irrigation by underground tunnels did not prevail, but the population amounted to many times that of to-day. Ruins are found everywhere. The most noteworthy are naturally located near the present main sources of water close to the foot of the surrounding mountains. A large number of others are located in a zone farther removed from the mountains. Here the present density of population is less than that of earlier times, in spite of the fact that now a large part of the water used for irrigation comes from tunnels, while in the past all of it was derived from the surface. Finally, a third zone lies within both the others. It is now uninhabited and uninhabitable for lack of water, or else because the very slight supply of water is too saline for use. In mediaeval times a large number of villages, whose ruins still remain, were located in this area, deriving their water from the same surface streams which supplied the cities nearer the mountains. The history of Turfan, previous to about 800 A. D., is not known with sufficient exactness to warrant any conclusions as to early conditions. There seems to be little room for doubt that since 800 A. D. the climate has changed greatly for the worse.[11]

(5) *The irrigation canals of Son Kul.*—In Kashmir and in the Lop basin, there is, as we have seen, a shadowing forth of a period of great aridity about five or six hundred years after Christ. The little basin of Son Kul at an elevation of 10,000 feet on the Tian Shan plateau, northwest of the Lop basin, furnishes strong evidence of such a period. No means of dating it definitely have been found, but it is probable that it belongs to the same period as the dry time of Kashmir and Lop. On the mountains surrounding the small lake of Son Kul a number of old irrigation canals may be seen. At present the climate is so cold that snow falls during every month of the year. In July, 1903, the writer saw ice on the edges of the brooks. The only inhabitants are a few Khirghiz nomads who bring their flocks up to the mountains about the first of July to feed on the rich grass for a few weeks. Agriculture is utterly out of the question; yet the nature of the canals, their size and length, and the fact that they occur not in one place only, but several, prove that they must have been made for the purpose of irrigating fields on the smooth gentle slopes to which they lead. The age of the canals is so great that they have been a good deal filled and smoothed away by the movement of waste on the hillsides. Nevertheless they are still perfectly distinct and unmistakable, and therefore can scarcely be more than a few thousand years old at most.[12]

(6) *Seyistan and Persia.*—The basin of Seyistan,[13] in eastern Persia furnishes evidence much like that of Lop Nor. Distinct elevated beaches, which the writer has described at length in Exploration in Turkestan, here surround a large swampy lake which has no outlet except an occasional overflow to an adjoining body of salt water at practically the same level. The locations of ruins indicate that during the time when the region was most densely populated, the lake stood at a high level. Tradition says that the lake once covered the whole country. King Solomon, it is averred, saw that if the water were removed the lake bottom would make excellent land for melons, wheat, and other good things. Therefore he set his genii to work to fill it. At the same time the springs dried up when trodden upon by a legendary hero. Ruins are reported in the middle of what is now one of the chief bays of the lake. If the report is true, the ruins probably bear witness to a dry period similar to that of which we have already found evidence elsewhere. Tradition, historic record, and the location of ruins all indicate that during the middle ages the lake was for a second time larger than now. Abundant evidence in other parts of Persia suggests desiccation. The time of occurrence of the early and mediæval cool, moist, epochs and of the intermediate dry epochs agree with those in the other basins.[14]

(7) *The Turkish Lake of Gyul-jük.*—The little Lake of Gyul-jük, lying 4,000 feet above the sea among the Taurus mountains in Armenia, furnishes an interesting suggestion of the effect which the inferred dry epoch in the early part of the Christian era may have had even in a fairly well watered land like Turkey. At present the lake overflows in moist seasons and has no outlet in times of drought. In the middle of the lake lies an island surrounded by water at least 30 feet deep. Local tradition asserts that this island was once part of the main land, and that the western portion of the lake occupies what was formerly a plain with a brook flowing thru it. There must be a considerable amount of truth in the tradition, for the island is covered with the ruins of an ancient Armenian monastery, and in the surrounding water numerous ruins of houses or other buildings can be seen submerged to a depth of perhaps 15 feet. According to the native Armenians of this region an account of the monastery was preserved in a book which was destroyed during the sad massacres of 1895–96. The monastery is surely a thousand years old, and probably twelve or thirteen hundred. It seems to have been built upon the dry bed of the lake at a time when all Asia suffered from a few centuries of drought some five or six hundred years after Christ.[15]

[9] See The Pulse of Asia, p. 270; also, S. Beal: Si-Yu-Ki. London. 1884; and the same author's translation of the life of Huien Tsiang.. London 1888.

[10] For a full discussion of the varied phenomena of Lop Nor and the Lop basin see The Pulse of Asia, Chapters VI–X, XII–XIV.

[11] See The Pulse of Asia, Chap. XV.

[12] See W. M. Davis: Explorations in Turkestan (Pumpelly Expedition of 1903). Washington. 1905. p. 115; and The Pulse of Asia, p. 351–3.

[13] Often spelled Seistan and Sistan, but pronounced Seyistan.

[14] See "Explorations in Turkestan." Washington. 1905. p. 302-315.

[15] See The Pulse of Asia, p. 353–6.

(8) *The Caspian Sea.*—The Caspian Sea offers an epitome of the climatic history of Asia. Here, as in so many other cases, an expansion of this sea indicates either an increased supply of water or a lowering of temperature with a consequent diminution in the rate of evaporation. A study of the beaches and deposits of the sea itself, and of numerous ancient accounts by Herodotus, Pliny, and others indicates that at the time of Christ and earlier the level of the sea was so high that a long bay reached eastward toward the Sea of Aral. Ships passed from the Caspian Sea into the Oxus river, apparently by way of the Sea of Aral, which at that time must have been so full as to overflow, altho now it has no outlet. During the fifth or sixth century of our era conditions were very different. At Aboskun on the southeast side of the Caspian, at Derbent on the west, and at other points the remains of walls, forts, and other structures indicate that what is now the bottom of the sea was then dry land. Warping or other movements of the earth's crust do not offer an adequate explanation of the phenomena, since the waterspread of the lake appears to have diminished, which would not be the case if there had been no change of climate. If the climate had remained uniform the amount of surface exposed to evaporation would also have remained uniform.

In the middle ages the surface of the sea again stood higher for many hundred years than it now does, as appears from the data furnished by numerous Arab writers who speak of the water as standing at the level of a tomb in Baku, or a wall at Derbent, or at other still recognizable points at specified times. Altogether there seems to be very clear evidence that the Caspian Sea has past thru fluctuations corresponding exactly to the changes of climate which we have inferred elsewhere. Their course is illustrated in the accompanying diagram. It is not to be supposed that the mediaeval period of comparatively moist conditions was notable in moist regions. In such regions its effects would probably be too small to be noticed, altho in very dry regions they might be important.

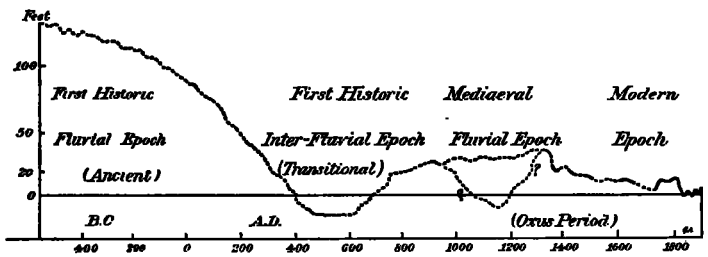

FIG. 1.—Approximate changes in level of the Caspian Sea. (Referred to Brückner's datum-level, 85 ± feet below sea-level.) From "The Pulse of Asia." p. 349.

The most notable fact in connection with the climatic history of the basins described above is that the same sort of changes appear to have taken place in all of them simultaneously so far as dates can be obtained. An epoch of comparatively cool, moist climate seems to have prevailed previous to the beginning of our era and for a short time thereafter. Then there was a somewhat rapid dessication culminating about the sixth century, and characterized by a climate even drier than that of to-day. In the middle ages conditions again improved from the point of view of arid countries, altho there is a little evidence of a dry time in the eleventh or twelfth century. Since about 1300 A. D. there has been a general tendency toward drier or warmer conditions, altho during the present century there has been little or no change.

Wide distribution of evidence in both latitude and longitude.—Changes of climate appear to have been by no means limited to the central parts of Asia. In the far southeast the lake of Yunan, in southern China, has no outlet. A tradition is preserved among the Chinese to the effect that it was once much more extensive. In Mongolia, to the north, there are numerous ruins and lakes which seem to be of the same sort as those described above, altho they have not been critically examined. On the other side of the continent Arabia is full of ruins in places which are now almost waterless, and ancient writers on the country almost universally speak of it in terms which imply an abundance of water far in excess of that which now exists. For instance, Ptolemy gives the location of the sources of five rivers and of the mouths of three, altho now not a single stream deserves to be called a river. He locates another river near Palmyra, where vast ruins indicate that the ancient city must have had a population of one hundred thousand or two hundred thousand people, altho now the water supply is scarcely sufficient for a thousand.

In Roman times Palmyra was famous for the excellence of its water; to-day the water from the same sources is so sulfurous that the guide-books advise people to take drinking water with them from springs one or two days' journey to the west. Earthquakes, war, the destruction of ancient irrigation works, and the inroads of an uncultured nomadic population have all been assigned as the cause of the decay of Palmyra and of the decrease in its water supply. It is a significant fact, however, that travelers who visited the ruins in 1889, at the end of a series of years of unusually heavy rainfall, found that the water was not only more abundant than at other times but also much sweeter. This seems to indicate that if the mean rainfall were to become permanently larger than it now is, or if the temperature were to become lower so that evaporation were diminished, the supply of water at Palmyra would become correspondingly larger, and conditions like those of ancient times would once more prevail.

South of Palmyra the great Syrian Desert was formerly traversed by large caravans of merchants who past from Bosra or Petra to the Persian Gulf. To-day the routes which they followed are utterly impracticable for lack of water. War or the raids of nomads might cause such routes to be abandoned temporarily for scores or possibly hundreds of years, but no war or raid could cause the total disappearance of the springs or oases upon which the travelers of ancient times relied.[16]

In Africa and Europe the subject of changes of climate has not been studied exhaustively. On the whole it seems to the writer that the evidence indicates quite clearly that North Africa has suffered changes like those of Asia. In Europe the evidence seems to be inconclusive.

North Africa is full of ruins and other phenomena which, like those in Asia, seem to be most reasonably explained on the assumption of a change of climate. Herodotus, for instance, tells of traveling with oxen over routes where the ox could not possibly be used at present. Numerous writers have exprest the belief that, as Lahache[17] puts it, there are many places "where it would to-day be absolutely impossible to obtain, even from very far, the quantities of water which the Romans there utilized." This statement is important because Lahache feels obliged to make it in spite of the fact that he is trying to show that at the present time the climate of North Africa is not changing and that France need not fear that increasing aridity will add to her other colonial difficulties. It should be stated that many writers do not agree with Lahache as to the climate of past times. They hold that ancient Roman accounts of the country prove it to have been then, as now, a land of scanty rainfall bordering a desert, and fit for agriculture only in places where water is available for irrigation. Their arguments lack the quantitative element which alone can lead to certainty.

The possibility of changes of climate in Europe has not been much discust. Gibbon concluded that the climate has changed

[16] See The Climate of Ancient Palestine. Bul. Amer. geog. soc, 1908, 40: September, October, and November.

[17] Lahache: Le deséchement de l'Afrique francaise est-il demontré? Bul. soc. de geog. de Marseille, 1907, 31: 182.

notably during the last two thousand years. In the days of the Teutonic barbarians both the reindeer and the elk, he says, roamed in the forests of Germany and Poland. To-day the reindeer can not subsist in regions so far south. At the same remote period, according to Gibbon, our barbarian ancestors crost the Rhine and the Rhone upon bridges of ice, altho in modern times these rivers never freeze sufficiently to allow of this. On the other hand Eginitis,[18] in the annales of the Observatory of Athens, sets forth various reasons for believing that there has been no change. He bases his arguments chiefly upon botanical evidence such as the kind of crops grown in certain regions, dates of flowering, time of harvest, and so forth. The great variability of plants, and the degree to which they are affected by cultivation, and the ease with which they accommodate themselves to a new environment renders any conclusions drawn from vegetation uncertain unless supported by other evidence. The same is doubtless true of animals. If Gibbon is right about the ice, however, the climate of Europe must have suffered a change similar to that which seems to have taken place in Asia.

The geographical location of the evidences of changes of climate is a subject in regard to which there is much misconception. In his recent excellent work entitled "Climate," Ward,[19] who opposes the idea of any important climatic changes during historic times, expresses himself thus: "It is a very striking fact that the districts from which comes most of the evidence of changes of climate within historical times are subtropical or subequatorial, i. e., they are in just those latitudes in which a slightly greater or a slightly less migration of the rain-bringing conditions easily produces a very considerable increase or decrease in the annual rainfall." Such an assertion is true for Africa, to which Ward has chiefly confined his attention. It is by no means true for Asia. Of the eight basins discust above, none is subequatorial. One, that of Seyistan in latitude 30° N. is distinctly subtropical, and Gyul-jük, 38° N., lies on the edge of subtropical regions. Kashmir, in latitude 34° N., may also be regarded as subtropical, altho its position north of the first great range of the Himalayas subjects it to conditions different from those of ordinary regions in the subtropical zone. Pangong (in western Thibet) lies in the same latitude as Kashmir, but its location beyond or northeast of the whole body of the Himalayas gives its climate little resemblance to that of other subtropical countries. The rest of the basins lie well beyond the limits of what are usually called subtropical regions. The huge basin of Lop extends from latitude 36° N. to 43° N. Turfan lies entirely between 42° N. and 44° N., and Son Kul likewise. The limits of the Caspian basin extended from 35° N. to 60° N. The northern parts of this basin may fairly be omitted from consideration, but Russian observers have recorded a good deal of evidence which indicates that numerous small lakes in latitude 45° N. to 50° N., northeast of the Caspian, are, on the whole, decreasing in size, altho they fluctuate more or less. The same is true of Lake Balkash farther east in latitude 45° N. These regions, like Son Kul and Turfan and much of the Lop basin, receive summer rains, and have a climate of a distinctly temperate continental type. The fact seems to be that evidences of changes of climate have been reported in large numbers from subtropical regions, not merely because those regions are on the borders of diverse climatic zones, but also because they are dry enough to be sensibly affected by changes of climate which are not noticeable in moister parts of the world. The evidence of change seems to be found in all dry regions wherever they are located. It would be rash to conclude that climate has not changed even in Europe. In that continent a moderate change in either direction would produce few results which could be recognized after a lapse of hundreds of years except in countries such as Spain and Greece which are at present suffering from aridity, or in countries such as northern Russia which would be greatly influenced by a decrease in the length of summer.

[*To be continued.*]

[18] See a fuller summary of Eginitis' work in the Monthly Weather Review, December, 1898, 26:554.—*C. A.*

[19] R. DeC. Ward: Climate. New York. 1908. p. 351.

NOTES ON THE CLIMATE OF EASTERN ASIA.

By Prof. ALFRED J. HENRY. Dated Washington, D. C., July 24, 1907.

In point of magnitude and diversity of physical features, the Continent of Asia stands preeminent among the grand divisions of the earth. Its greatest length is about 7,000 miles, and its width from Northeast Cape to the southern extremity of the Malay Peninsula is about 5,300 miles. It contains the greatest unbroken land mass on the globe, and its eastern shore is washt by an equally great water surface, thus affording an opportunity for the creation of two highly developed climates of directly opposite types.

Each of these great surfaces, the land and the water, has its own distinctive atmosphere each of which differs from the other in point of temperature, density, and moisture. These differences arise chiefly because water, on account of its high specific heat, warms more slowly and to a less degree than land. Likewise the loss of heat by radiation is much smaller from a water than from a land surface. As a consequence of the operation of those two processes, the atmosphere overlying the great plains of Asia becomes very much warmer in summer and decidedly colder in winter than that which overlies the oceans to the east and south. When the continent becomes warmer than the ocean, there is an inflow of air from the sea toward the interior, and conversely, when the temperature of the interior falls below that of the adjacent oceans, the flow is from the interior outward toward the oceans.

In winter, the continental influence is the dominating factor. As the sun recedes from northern latitudes, intense radiation of heat from the vast Siberian plains sets in and soon the amount of heat thus lost exceeds the amount received. The lower layers of the atmosphere are also cooled by contact with the frozen ground and doubtless by the slow descent of the cold air from aloft. There is thus gradually built up over these Siberian plains a semipermanent area of cold air of such proportions that it almost completely dominates the weather of eastern and central Asia. This mass of cold air, or the Siberian high, as it is commonly called, is the seat of the greatest known cold on the globe; cold north winds proceed out of it and sweep to the southward over Manchuria, Mongolia, Corea, and northern China.

It is important to note in this connection that, by reason of the modifying influence of the rotation of the earth on its axis, a body set in motion in the Northern Hemisphere is constantly deflected to the right, hence, the northerly winds which issue from the Siberian high become northeast some distance south of their origin as on the central and northern Chinese coast, and become east winds still farther south in the vicinity of Hongkong. The north and northwest winds in coming from a cold interior are dry winds, hence, there is very little precipitation in Siberia, Manchuria, Korea, and northern China in the cold season.

In summer, the oceanic influence is the controlling factor. As the meridian altitude of the sun increases, the cold air of the interior is gradually replaced by warm and consequently light air. The balance of pressure is then shifted from the interior to the surrounding oceans, hence a change in the winds, viz, from a northerly to a southerly quarter. Northerly winds are cold and dry; southerly warm and moist. The rainfall of eastern Asia comes with southerly winds.

The above brief sketch presents the broad features of the general circulation of the atmosphere in its relation to climate.